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JUL 77 J G LUHMANN , J B BLAKE F04701-76-C-0077
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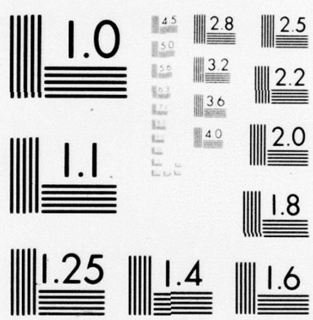

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REPORT SAMSO-TR-77-140

K-Shell X-Ray Fluxes at Satellite Altitude From Proton Precipitation

Space Sciences Laboratory
The Ivan A. Getting Laboratories
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El Segundo, Calif. 90245

15 July 1977

Interim Report

APPROVED FOR PUBLIC RELEASE:
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Prepared for
SPACE AND MISSILE SYSTEMS ORGANIZATION
AIR FORCE SYSTEMS COMMAND
Los Angeles Air Force Station
P.O. Box 92960, Worldway Postal Center
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This interim report was submitted by The Aerospace Corporation, El Segundo, CA 90245, under Contract No. F04701-76-C-0077 with the Space and Missile Systems Organization, Deputy for Advanced Space Programs, P.O. Box 92960, Worldway Postal Center, Los Angeles, CA 90009. It was reviewed and approved for The Aerospace Corporation by G. A. Paulikas, Director, Space Sciences Laboratory. Lieutenant Dara Batki, SAMSO/YAPT, was the project officer for Advanced Space Programs.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication. Publication of this report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.

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19 REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 18 SAMSO-TR-77-140	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 K-SHELL X-RAY FLUXES AT SATELLITE ALTITUDE FROM PROTON PRECIPITATION.		5. TYPE OF REPORT & PERIOD COVERED Interim rept.
		6. PERFORMING ORG. REPORT NUMBER 14 TR-0077(2260-20)-12
7. AUTHOR(s) 10 Janet G. Luhmann and J. Bernard Blake		8. CONTRACT OR GRANT NUMBER(s) 15 F04701-76-C-0077
9. PERFORMING ORGANIZATION NAME AND ADDRESS The Aerospace Corporation El Segundo, Calif. 90245		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Space and Missile Systems Organization Air Force Systems Command Los Angeles, Calif. 90009		12. REPORT DATE 11 15 July 1977
		13. NUMBER OF PAGES 10
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) 12 12p.		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Proton Precipitation
X rays

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A sample calculation is presented of K-shell x-ray emission resulting from energetic proton precipitation into the upper atmosphere. It is found that intense fluxes of K-shell x-rays at low satellite altitudes can result from observed fluxes of precipitating protons.

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CONTENTS

FIGURES

1. INTRODUCTION

Luhmann and Blake (1977) have presented sample calculations of the soft bremsstrahlung and K-shell x-rays (0.10 keV to 10 keV) present at low satellite altitude resulting from the precipitation of electrons into the upper atmosphere. Since proton precipitation occurs also, it is of interest to determine if such precipitation results in a detectable x-ray signal. It happens that the proton bremsstrahlung cross-section is negligible but the cross-section for producing K-shell x-rays by proton impact upon nitrogen and oxygen is significant above a few tens of keV.

In this paper a sample calculation is presented based upon a satellite measurement of proton precipitation. The general question of the detectability of x-rays from proton precipitation is discussed briefly.

2. CALCULATIONS

The cross-section for the production of K-shell x-rays by protons impinging upon oxygen, nitrogen and argon are required for the calculation. Measured cross sections have been presented by Hart et al. (1969) for protons with energies between 20 keV and 100 keV impinging on oxygen. Data are available also for the production of K-shell x-rays by protons with energies between 15 keV and 1900 keV impacting carbon, magnesium and other heavier elements (Khan et al., 1965). In the absence of measurements, these latter data were used in concert with well-understood theoretical principles (Merzbacher and Lewis, 1958; Madison and Merzbacher, 1975) to provide the cross-sections for K-shell x-ray production by protons with energies from 20 keV to 700 keV impinging upon nitrogen, oxygen and argon.

The calculation was performed as described in Luhmann and Blake (1977) by substituting the proton K-shell cross-sections described above for the electron cross-sections given by Tawara et al. (1973), replacing an electron range-energy relationship by one for protons, and deleting the bremsstrahlung formalism.

The cross-sections used in the calculation are shown in Figure 1. It is clear from Figure 1 that proton energies of several tens of keV are required to excite appreciable K-shell emission in oxygen and nitrogen and that hundreds of keV are required in the case of argon.

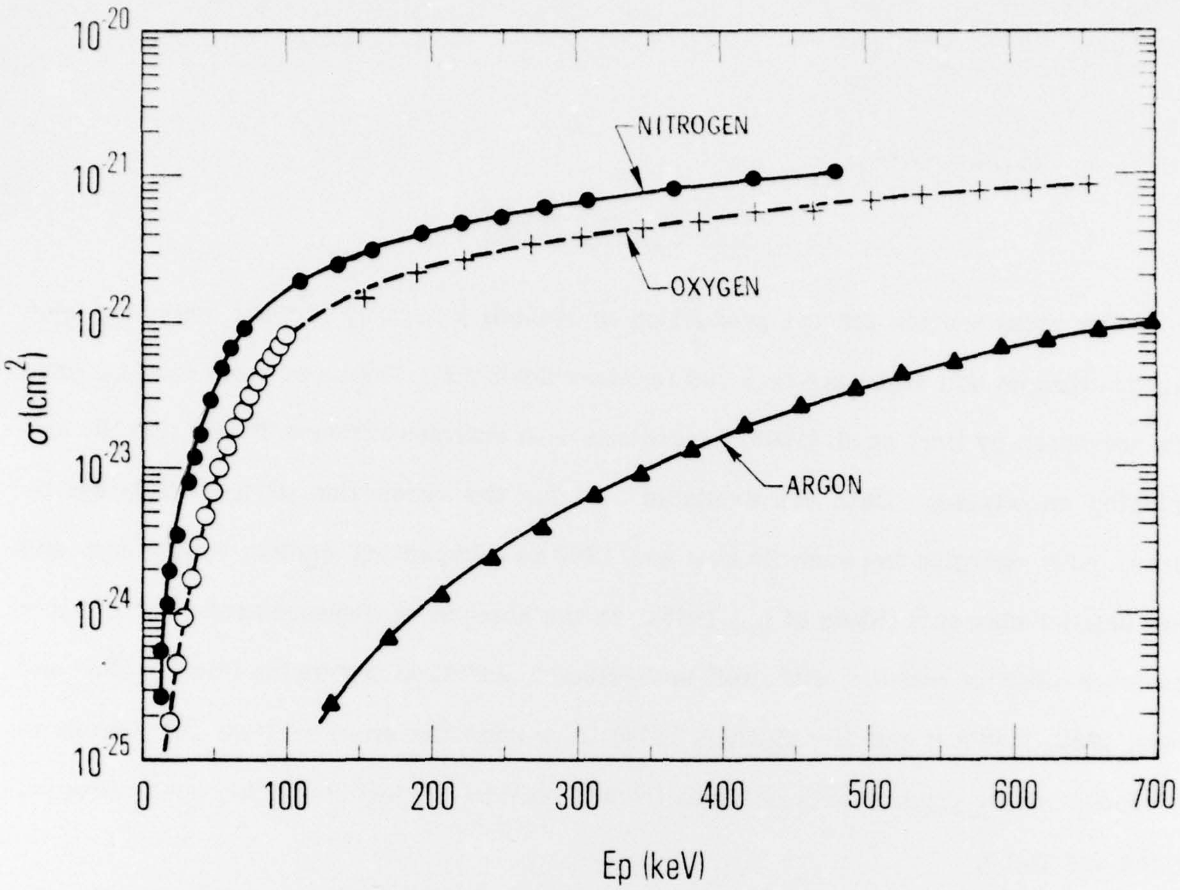

Fig. 1. K-Shell X-Ray Cross-Sections (p,x).

The proton precipitation flux, spectra and pitch-angle distribution used in this sample calculation were observed during the solar particle event which began on 11 April 1969; the specific data were obtained at 75570 sec UT on 14 April. These measurements are described in detail by Blake and Vampola (1974). Figures 2 and 3 are adapted from their paper. Figure 2 shows the measured proton and electron fluxes during a polar cap transverse by the OV1-19 satellite. The proton energy spectrum observed at 75570 sec UT is shown in Figure 3. Note that at the location of the peak proton precipitation intensities, the energetic electron (E > 100 keV) precipitation is nil. Unfortunately, no measurements of auroral energy electrons were made aboard the spacecraft, and thus possible K-shell x-ray emission due to auroral electron precipitation cannot be calculated.

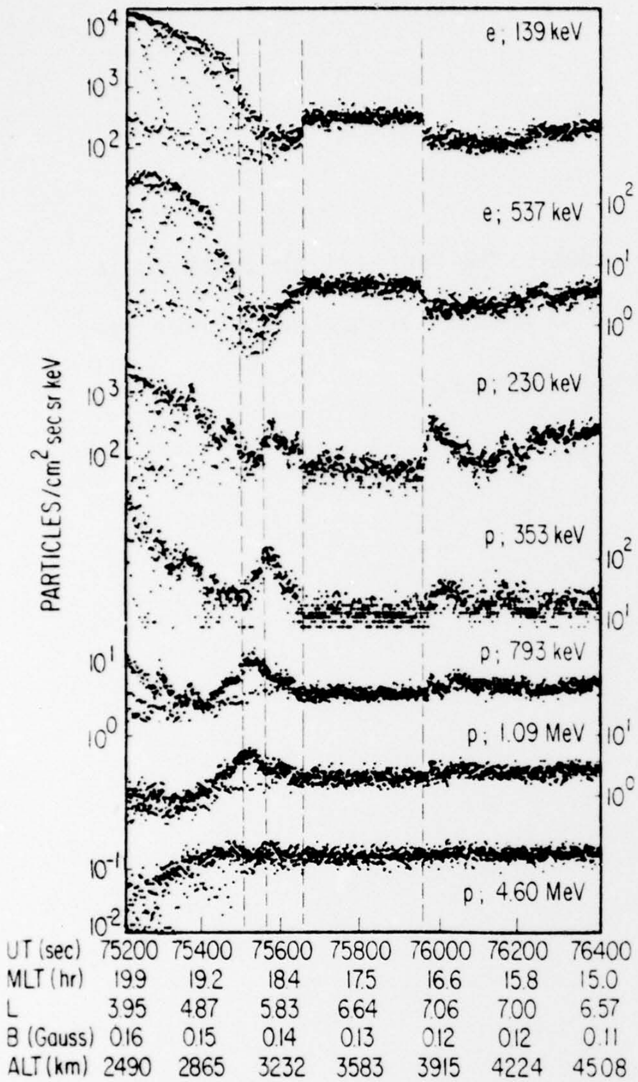

Fig. 2. Satellite Measurements of Proton and Electron Fluxes on 14 April 1969.

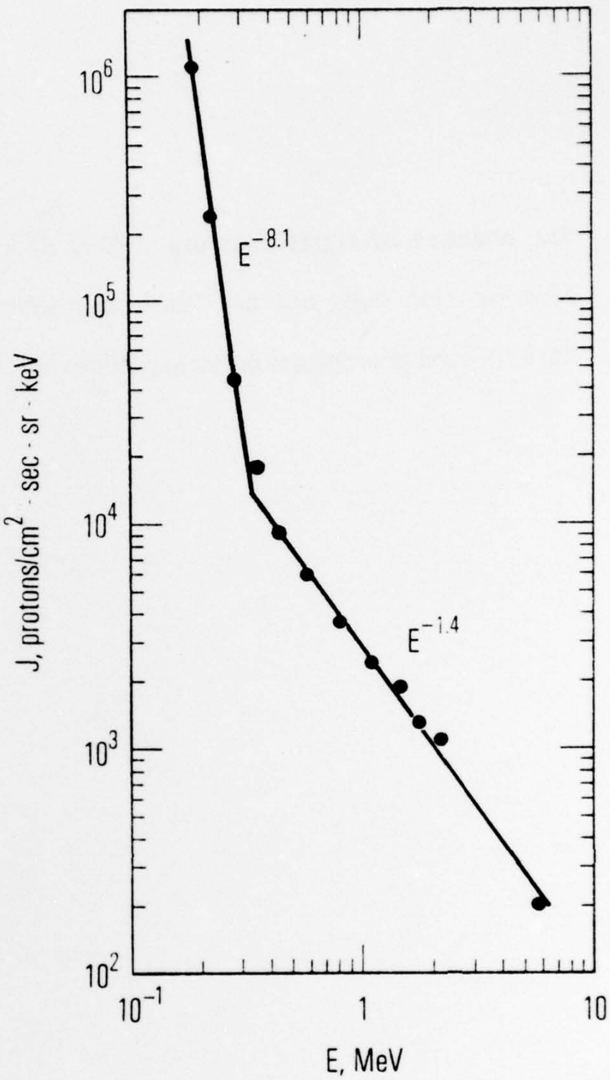

Fig. 3. Proton Energy Spectrum as observed at 75570 sec UT on 14 April 1969. (See Fig. 2.)

The present calculation yields the following K-shell x-ray fluxes at satellite altitude due to the observed proton spectrum shown in Figure 3:

Nitrogen:	$4 \times 10^7 cm^2$-sec;
Oxygen:	$2 \times 10^7 /cm^2$-sec;
Argon:	$7 \times 10^{-2} /cm^2$-sec.

The absence of significant argon K-shell x-rays is due to the fact that the proton-argon cross-section does not become appreciable (Figure 1) until an energy where there was little proton precipitation during the event depicted in Figure 2.

3. DISCUSSION

It is clear from the energy dependence of the K-shell cross-sections that normal auroral-energy proton precipitation will not cause significant K-shell x-ray emission from upper atmospheric nitrogen or oxygen. However, the sample calculation does show that intense fluxes of K-shell x-rays from nitrogen and oxygen result from the more energetic proton precipitation events that have been observed. (It should be noted that the proton precipitation shown in Figure 2, although occurring during a solar-particle event, does not simply consist of solar protons. The protons were accelerated by magnetospheric processes. Whether or not they were solar protons, with energies well above typical solar wind energies before magnetospheric acceleration, could not be determined (Blake and Vampola, 1974)).

Since the protons generate no bremsstrahlung continuum, x-ray emission from precipitating protons and that from precipitating electrons differs in a readily detectable fashion. If only K-shell lines are present, the precipitation consists of protons, not electrons. The shape of the bremsstrahlung spectrum, if present, reveals some information about the spectrum of the precipitating energetic electrons (Imhof et al., 1975a, 1975b; Luhmann and Blake, 1977). Thus satellite x-ray measurements which span the energy range from ~ 300 eV to ~ 300 keV will permit remote sensing of electron and energetic proton precipitation.

4. REFERENCES

Blake, J. B. and Vampola, A. L.	1974	in Correlated interplanetary and Magnetospheric Observations, (ed. D.E. Page), 173, Reidel, Dorchecht, Holland.
Hart, R. R., Reuter, F. W. and Smith, H. P.	1969	Phys. Rev. 179, 4.
Imhof, W. L., Nakano, G. H. Gains, E. E. and Reagan, J. B.	1975a	J. Geophys. Res. 80, 3622.
Imhof, W. L., Nakano, G. H. and Reagan, J. B.	1975b	J. Geophys. Res. 80, 3629.
Khan, J. M., Potter, D. L., and Worley, R. D.	1965	Phys. Rev. 139, A1735
Luhmann, J. G. and Blake, J. B.	1977	J. Atmos. Terr. Phys. (in press).
Madison, D. H. and Merzbacher, E.	1975	in Atomic Inner-Shell Processes, (ed. B. Crasemann) 1, Academic Press, New York.
Merzbacher, E. and Lewis, H. W.	1958	in Handbuch der Physik, (ed. S. Flügge), 34, 66, Springer-Verlag, Berlin.
Tawara, H. Harrison, K. G., and de Heer, F. J.	1973	Physica 63, 351.

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